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INNOVATIVE APPROACHES TO ENHANCING ENVIRONMENTAL SAFETY IN MODERN CONSTRUCTION

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The article is dedicated to the research and analysis of the most widespread voluntary standards of "green" construction. "Green" construction has been receiving significant attention since the beginning of the 21st century due to growing concerns about the environmental state. The increasing demand for "green" buildings has led to the necessity of their evaluation, namely certification of these buildings according to a set of defined criteria. This has contributed to the emergence of numerous systems for evaluating "green" construction.

Current challenges are highlighted, including the energy crisis and deterioration of the environmental state, which are relevant due to the high energy consumption of the construction industry. It is noted that the construction sector is a significant source of greenhouse gas emissions, necessitating the implementation of sustainable development strategies.

The study analyzes the main standards of BREEAM, LEED, and generalizes the categories of their assessment. Successful examples of implementing "green" construction in various countries such as the USA, UK, Australia, Canada, and Japan are analyzed. Emphasis is placed on the importance of government support in the development of environmental construction.

Examples of successful projects that have received BREEAM and LEED certificates in Ukraine are provided. Measures for Ukraine are proposed: increasing the popularity of certification according to BREEAM and LEED standards; activating state participation in environmental construction projects; using the experience of other countries to develop its own "green" construction standards.

It is concluded that "green" construction contributes to the increase in the value of buildings, provides a better environment for living and working, and promotes the durability and quality of building materials and solutions. It is established that the certification of "green" construction plays a key role in reducing the negative impact on the environment, increasing energy efficiency, improving the quality of life, and stimulating economic growth through the implementation of innovative and sustainable practices in the construction industry. The article emphasizes that the implementation of "green" construction is an important step towards sustainable development and improving the environmental situation in Ukraine and the world.

Key words: *"green" construction, sustainable development, voluntary standards BREEAM, LEED.*

Барулін Д. С. Інноваційні підходи до підвищення екологічної безпеки в сучасному будівництві

Стаття присвячена дослідженню та аналізу найпоширеніших добровільних стандартів «зеленого» будівництва. «Зеленому» будівництву приділено велику увагу на початку XXI століття через зростання занепокоєння щодо екологічного стану навколишнього середовища. Зростання попиту на «зелені» будівлі призвело до необхідності певної їх оцінки, а саме сертифікації цих будівель за набором визначених критеріїв. Це сприяло появі численних систем оцінки «зеленого» будівництва.

Висвітлено сучасні виклики, зокрема енергетичну кризу та погіршення екологічного стану, які є актуальними через високе енергоспоживання будівельної галузі. Зазначено, що будівельний сектор є значним джерелом викидів парникових газів, що потребує впровадження стратегій сталого розвитку.

У дослідженні виконано аналіз основних стандартів BREEAM, LEED, узагальнено категорії їх оцінювання. Проаналізовано успішні приклади впровадження «зеленого» будівництва у різних країнах, таких як США, Великобританія, Австралія, Канада та Японія. Наголошено на важливості державної підтримки у розвитку екологічного будівництва.

Наведені приклади успішних проектів, які отримали сертифікати BREEAM та LEED в Україні. Запропоновані заходи для України: підвищення популярності сертифікації за стандартами BREEAM та LEED; активізація державної участі у проектах екологічного будівництва; використання досвіду інших країн для розвитку власних стандартів «зеленого» будівництва.

Зроблено висновок, що «зелене» будівництво сприяє підвищенню вартості будівель, забезпечує краще середовище для життя та роботи, а також сприяє довговічності та якості будівельних матеріалів і рішень. Встановлено, що сертифікація «зеленого» будівництва відіграє ключову роль у зменшенні негативного впливу на довкілля, підвищенні енергоефективності, покращенні якості життя та стимулюванні економічного зростання через впровадження інноваційних та сталих практик у будівельній галузі. Стаття підкреслює, що впровадження «зеленого» будівництва є важливим кроком на шляху до сталого розвитку та покращення екологічної ситуації в Україні та світі.

Ключові слова: *«зелене» будівництво, сталий розвиток, добровільні стандарти BREEAM, LEED*

Formulation of the problem. Amid the accelerated development of society and, undoubtedly, the economy, the energy deficit and deteriorating environmental conditions are the two main problems facing the world's population today. Currently, the construction industry has become the leading consumer of global energy reserves and various energy resources and is the primary source of environmental pollution worldwide. According to data from the UN Environment Programme, the overall energy consumption in the construction sector accounts for approximately 30–40% of total energy consumption globally [1].

In Europe, energy use in residential and commercial buildings accounts for over 40% of total final consumption, making buildings the most energy-consuming sector and the primary source of greenhouse gas emissions [2]. However, this proportion pertains only to "operational" energy use, which is consumed for heating, cooling, ventilation, and other means that make the building habitable and support the constant needs of its inhabitants. There is additional energy consumption and associated greenhouse gas emissions linked to the construction process, building materials, and the characteristics of open urban spaces, where microclimatic and other processes significantly affect people's dependence on energy-intensive buildings and urban transport.

In 2020, carbon dioxide emissions in the construction sector reached 11.79 gigatons, accounting for 37% of all carbon emissions worldwide. Overall, 17% of these were associated with operational carbon emissions in residential buildings [3]. Therefore, it is crucial to accelerate the implementation of sustainable development strategies to achieve carbon neutrality, as the world's climate continues to worsen.

The issue of energy intensity and energy efficiency, as well as the environmental friendliness of construction production, is particularly relevant at present. The development of green building should contribute to the unity of all the aforementioned requirements.

Green building is a systemic approach applied to the design, construction, and maintenance of buildings that are resource-efficient, maximally convenient for consumers, and minimally impactful on the natural environment.

Analysis of Recent Research and Publications. Significant contributions to the study of international green building assessment systems have been made by foreign scholars. First and foremost, it is worth mentioning the work of Bungau et al., which explores the importance of green buildings for sustainable environmental development, emphasizing the dilemmas and challenges faced by scholars and practitioners in this field [1]. According to data from the UN Environment Programme, the overall energy consumption in the construction industry accounts for approximately 30–40% of global energy consumption. This underscores the importance of transitioning to energy-efficient and environmentally friendly buildings.

Other researchers also actively investigate various aspects of green building. For example, in the study by Pearlmutter et al., the importance of integrating natural systems into the urban environment is discussed, which contributes to reducing carbon emissions and improving the quality of life for urban populations. The analysis of current global standards in the field of green building shows that they are aimed at enhancing the environmental, energy, and economic efficiency of buildings [2].

Conducting an analysis of recent research and publications on this topic in works [3–8], it can be concluded that green building is crucial for sustainable development, and there is a need to implement international standards and certifications to ensure high quality and environmental safety of buildings. However, the development of this trend in Ukraine is still in its infancy, highlighting the importance of further research and popularization of green building standards.

Presentation of the Main Research Material. Each nation charts its own course towards sustainable development policies, green building initiatives, and energy efficiency improvements. The quantity of buildings constructed to meet environmental standards has become a crucial indicator of sustainable development and the maturity of a country's ecological construction market. At the governmental level, laws and strategies are enacted that impact all economic sectors and shape the long-term developmental prospects of nations [4].

Among the primary objectives set by leading countries in environmental development are the following:

– a 20% reduction in greenhouse gas emissions compared to 1990 levels (the roadmap to a resource-efficient Europe by 2050);
– increasing energy efficiency (the roadmap for energy development by 2050);
– raising the proportion of energy resources derived from renewable sources in the economy (the roadmap for transitioning to a low-carbon economy by 2050) [5].

Modern global standards for regulating ecological parameters in the architectural and construction industry mainly address the environmental, energy, and economic efficiency of so-called "green buildings" and are developed as voluntary rating certification systems.

The concept of green building is not uniform and constant worldwide but is shaped according to the specifications of national and regional developments in the construction industry. The World Green Building Council (WorldGBC) defines a green building

as one aimed at reducing or completely eliminating negative impacts on the environment throughout its life cycle, while also having a positive impact on the local environment and climate [6]. Additionally, this concept is described by the United States Environmental Protection Agency (USEPA) as "the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation, and demolition" [1].

To evaluate and certify buildings in terms of energy and environmental efficiency in the global construction sector, official certification systems have been established. These systems assess and compare the quality of buildings based on energy and environmental aspects, prioritizing the reduction of energy consumption, utilization of natural resources, and the minimization of waste production and pollution from transporting building materials [7]. Obtaining certification involves a process where a preliminary assessment based on the project is first obtained (with the investor declaring that all criteria will be met), followed by verification and evaluation of the implemented solutions and the issuance of the final report [8]. Only after a thorough inspection of the completed building will the building assessment be finalized and the certificate issued.

There exists a variety of sustainability certifications for the constructed environment, such as BREEAM, LEED, DGNB, Green Star, HQE, Living Building Challenge, Nordic Swan, WELL, GREEN HOMES, and more.

Let's delve deeper into the most prominent standards, BREEAM and LEED, which enjoy widespread adoption globally.

In 1990, the British firm BRE Global pioneered the voluntary BREEAM standard (Building Research Establishment Environmental Assessment Method) as a means of evaluating the environmental performance of buildings. BREEAM evaluates both the quality and direct environmental impact of buildings.

In 1998, the U.S. Green Building Council introduced the voluntary LEED standard (Leadership in Energy and Environmental Design). LEED equips building owners and managers with the tools necessary to identify and integrate suitable solutions for environmentally conscious design, construction, and building operation.

Voluntary standards are founded upon the integration of scientific research and technologies to meet contemporary demands for global adoption of "green building" principles.

The voluntary standards BREEAM and LEED encompass a range of criteria (approximately 100–110), which can be categorized to assess the energy and environmental efficiency of buildings (Fig. 1) [9, 10].

Currently, the adoption of LEED and BREEAM methodologies for certification is not widespread in Ukraine, but there is a rapid growth in green construction. It is crucial for the state to participate in these initiatives and foster the development of green construction.

In Ukraine, only a few buildings have obtained "green" certificates so far. However, in 2020, the first BREEAM certification was achieved for the residential building of the DIADANS complex in the Pechersk district of Kyiv. Additionally, the B12 UNIT. City building was awarded a LEED silver-level certificate. Previously, the U.S. Embassy in Ukraine and Shell's office in the Toronto-Kyiv Business Center had obtained LEED certification. BREEAM certificates were also awarded to buildings such as the Forum Lviv shopping center in Lviv, the Astarta Business Center in Kyiv, and the Rive Gauche shopping center in Kyiv.

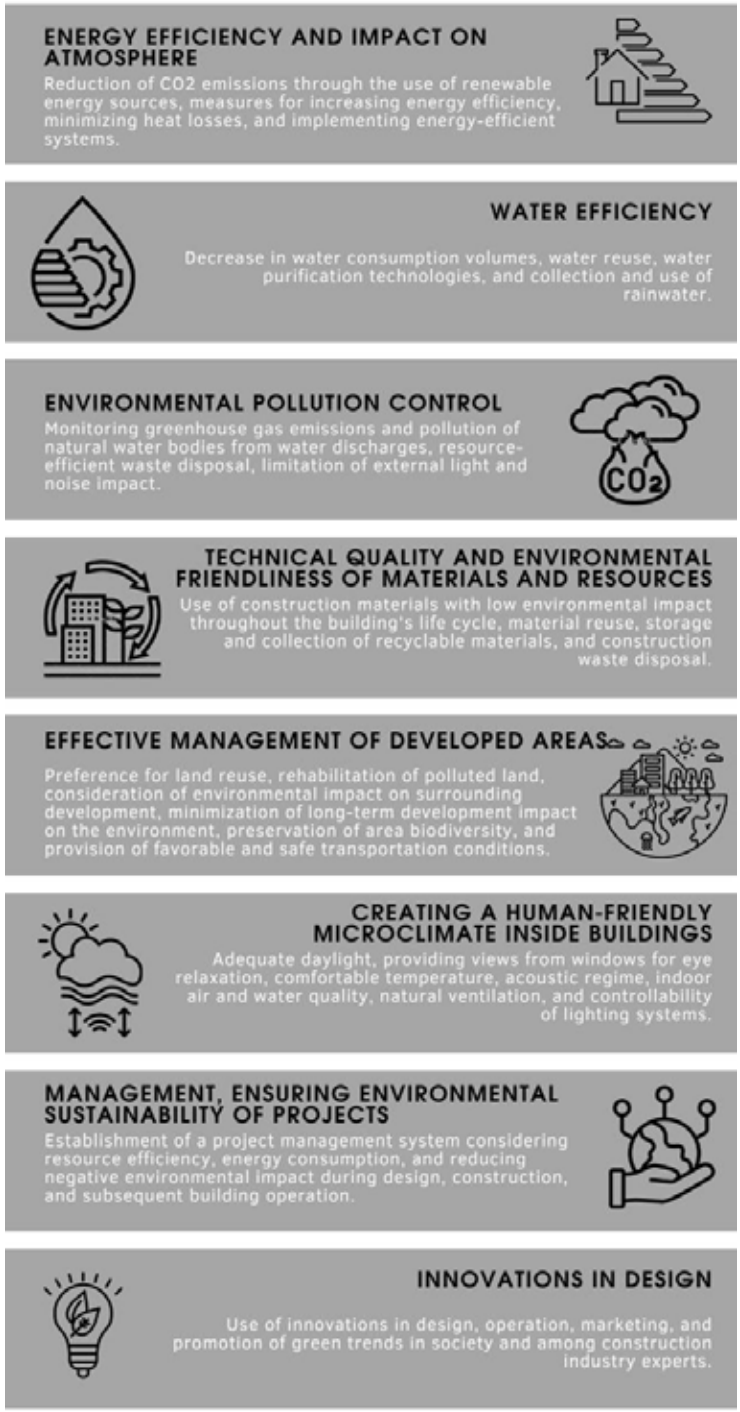

Fig. 1. Categories for assessing the standards of energy and environmental efficiency of buildings (based on voluntary standards BREEAM and LEED)

Conclusions. In summary, the integration of "green" construction into sustainable development has a rich history and widespread global adoption. This approach has garnered significant popularity in countries like the USA (LEED), the UK (BREEAM), and over 40 others (including Australia, Canada, Japan, etc.). While Ukraine may not have fully embraced the certification of "green" construction yet, such a sustainable approach should form the cornerstone of the country's post-war reconstruction policy.

Certifying "green" buildings not only enhances their value but also ensures the implementation of solutions that promote a healthier living and working environment. An eco-friendly building should prioritize the selection of appropriate building and finishing materials, as these materials significantly influence its energy requirements. The objective of sustainable construction is to promote durability, quality, and utility of materials, structural and design solutions, while also emphasizing environmental conservation (achieving synergy among social, environmental, and economic values).

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